Universitätsklinik Balgrist, Zürich
Klinik für Orthopädie
Direktor: Prof. Dr. med. Christian Gerber

Betreuung der Masterarbeit: Prof. Dr. med. Christian Gerber
Leitung der Masterarbeit: Prof. Dr. med. Christian Gerber

Deltopectoral versus Superolateral Approach for Reverse Shoulder Arthroplasty

MASTERARBEIT

zur Erlangung des akademischen Grades
Master of Medicine (M Med)
der Medizinischen Fakultät der Universität Zürich

vorgelegt von
Andrea Ottini (11-206-372)

2017

Table of Content

1 Abstract

Reverse total shoulder arthroplasty (RTSA) is a surgical procedure for the treatment of advanced shoulder destruction. It is best established for the treatment of irreparable rotator cuff tearing with painful pseudoparesis in the elderly. Its utilisation has rapidly grown with the aging of the population and the worldwide documentation of positive results. Nonetheless, the optimal surgical approach has not been yet defined. It was therefore the purpose of this study is to compare the outcome after either a deltopectoral or a superolateral approach, as these are the two most frequently used approaches for RTSA. In a prospective study, 27 primary shoulders needing RTSAs were randomly assigned to either approach and followed for a minimum of two years. There was no difference in clinical or radiographic outcome at any time-point of the study. Although the study is limited by its sample size, it was concluded that no one of the two approaches is clearly superior and that the specific advantages and drawbacks of each approach justify the respective choice according to the preoperative situation and the surgeon's expertise and preference.

2 Introduction

Currently RTSA is a classic treatment option for irreparable rotator cuff tear with pseudoparalysis.[1–4] Of the several surgical approaches that can be used, the deltopectoral (DP) and the superolateral (SL) approach are most frequent.[4–9]

Rotator cuff tear reflects an insufficiency of these muscles and is followed by disability of the shoulder, instability of the humeral head and ultimately secondary osteoarthritis. The humeral head migrates upward and impinges subacromially and under the acromioclavicular joint, leading to erosion of both skeletal components. Eventually, the soft atrophic humeral head collapses, producing "rotator cuff tear arthropathy" (CTA) with progressive painful pseudoparesis of shoulder elevation (defined as active anterior elevation < 90°, with full passive anterior elevation).[10–13] Although, this mechanism proposed by Neer et al. in 1983 does not explain the full pattern of CTA, the pseudoparalysis as the main clinical disability associated with a massive irreparable cuff tear is limiting activity of daily living and quality of life.[13,14] For this reason, the treatment of this pathology has always been a challenge for orthopedic surgeons.[3,11,14–19]

Several treatments have been proposed and the history goes back long time. The first design for shoulder arthroplasty was made in the late 1800s by Themistocles Gluck, who however, never published results of the implantation in humans. Therefore, the first published results are attributed to Jules Emile Péan who debrided a tuberculotic shoulder and implanted a platinium and rubber shoulder prosthesis. Shoulder arthroplasty played a secondary role in the treatment of shoulder problems, due to high failure rate, until 1955, when Neer described that 11 of 12 patients with a fractured humerus were successfully treated with shoulder hemiarthroplasty. Thereafter, in 1974, Neer described the use of his prosthesic design to treat glenohumeral osteoarthritis in 44 patients and reported good results.[19,20]

Although the design of the hemiarthroplasty proposed by Neer allowed good pain relief, variable results in strength and function, along with superior head migration and a high complication and revision rate have been described. This led him to propose the addition of a prosthetic glenoid component, presuming a better stability of the humeral head.[19]

In the early 1970s, surgeons conceived prostheses reversing the anatomic design of the shoulder, by placing the socket in the proximal humerus and the ball in the glenoid. This was designed to improve range of motion (ROM) and strength without increasing the migration rate. Many designs were proposed, such as that of Leeds in 1972, Kessel in 1973 or Kölbel and Friedebold in 1973.[19]

In 1985, Grammont proposed a new reverse prosthetic design that improved biomechanical stability by four principles whereby the third and fourth were *the* true innovations which ultimately led to the success of this implant: 1) inherent stability of the implant, 2) convex weight bearing part in the glenoid, 3) center of the sphere at or within the glenoid neck, and 4) medialized and lowered center or rotation.[9,19,21]

Since the time of its inception several biomechanical studies have allowed to improve the design of RTSA and to reduce clinical and mechanical complications. Currently, RTSA is not only used for CTA but for proximal humerus fractures, rheumatoid arthritis, osteoarthritis and revision arthroplasty.[1,13,19]

The increasing use of RTSA has come with different surgical approaches, such as: Neer's anterosuperior approach, Dumontier's SL approach, Augereau's DP approach, Grammont's transacromial approach and many others.[1,5,7,9,13,17,22]

Amongst the many approaches, only the DP and the SL are now recognized as standards procedures.[6,7,9]

2.1 Objective of the study

It was the purpose of this study to compare the DP and SL approach for RTSA in order to determine whether one approach is overall better than the other and/or if one approach has specific features, advantages or disadvantages. It is felt that depending on the precise pathology and the clinical setting, choosing the best approach could improve surgical ease and clinical outcome.

2.2 RTSA: Biomechanics

A brief introduction of the biomechanics in which the reverse prosthesis relies could ease and sustain the comprehension of the postoperative dynamical ROM-changes.

In CTA, joint forces distribute themselves in an unequal way because the upward facing force of the deltoid cannot be compensated by the downward facing "compressive" force of cuff muscles, since these muscle are not intact. This results in an altered concavity-compression phenomenon and a superior joint force vector > 30° to form the glenoid center with consequently upward migration of the humeral head and glenoid wear. Additionally, mechanical impingement at the glenohumeral joint erodes the bony components in time, resulting in instability, arthritic alterations and biochemical modification of the joint.[1,10,13,14,16,23–25]

In order to restore function of the shoulder, RTSA has been designed, finding its fully appositeness in the Grammont concept. This is based on 4 biomechanical principles.[21] (1) RTSA has a constrained and inherently stable design (less mismatch between the humeral head and the glenoid surfaces), (2) the scapular component must be convex and the humeral part must be concave (in order to have a convexity on the weightbearing part), (3) the center of the scapular "sphere" must be at or within the glenoid neck and (4) the center of rotation is medialized and distalized.[1,13,16,21,24,26]

The constrained "anatomical reversed" design gives stability to the prosthetic joint by scaling down the size mismatch between humeral head and glenoid surface and by fixing the center of rotation. This converts the upward facing force of the deltoid into a rotatory movement, restoring elevation. Additionally, the deep socket of the humeral head restores the concavity-compression with the ball of the joint, granting a bigger resistance to dislocating forces.[13,21,23,24]

The fact that the center of rotation is at or within the glenoid neck allows a diminution of the shear and torque forces at the glenoid-bone interface (this is the reason because other reverse prosthesis designs have failed to grant successful postoperative results).[13,21,24]

Lastly, Grammont et al. medialized and distalized the center of rotation. This lowers the arm relative to the acromion and augments the resting length of the deltoid muscle, thus almost doubling its force. Additionally, the deltoid muscle changes its morphology; fibers that lied medial migrate to the lateral side of the implant (becoming "abductors and elevators"). These biomechanical alterations augment the lever arm of the deltoid muscle and stabilize the glenohumeral joint. Intraoperatively, cuff muscles can potentially be reattached to their original insertions to support deltoid function, but reattachment of these muscles does not appear to be essential at least for improvement of overhead elevation.[1,13,21,23,24,26]

The design of the reverse prosthesis restores joint stability, increases active elevation, and reduces pain. Due to the biomechanical changes, external rotation (ER) cannot be effectively restored. Boileau et al. explain this with at least 4 reasons: The limited lateral offset of the glenosphere (center of rotation is at or within the glenoidal neck) limits the possibility to active externally rotating the shoulder joint by the deltoid. Second, by medializing the center of rotation the medial fibers lose their external rotation moment in favor of a better abduction and elevation strength. Third, the ER depends on the state of the posterior cuff muscles (if the infraspinatus or teres minor are fatty infiltrated). Lastly, during the operation (for example by posterior drilling of the screw holes) there is the possibility to damage the suprascapular nerve, thus reducing the infraspinatus rotation strength.[13,24,27]

3 Patients and methods

3.1 Inclusion and exclusion criteria

To be included, patients had to have an irreparable rotator cuff tear and chronic pseudoparalysis. The rotator cuff was considered to be irreparable if the chronic painful condition was associated with radiographic documentation of fatty infiltration >2 of the supraspinatus or infraspinatus according to the classification of Goutailler et al. and/or if the acromiohumeral distance was <7mm on a true antero-posterior radiograph of the shoulder.[11,12] Conservative treatment of at least three months had to have failed and the deltoid muscle had to be functional

Exclusion criteria consisted in current or previous infection, neuropathies (joint damage because of a neurological pathology), pronounced osteopenia with T-Score -1 to -2.5 according to the WHO-definition or destroyed bone of the scapular neck, revision of another shoulder prosthesis (excluding: humeral resurfacing), past medical history of systemic steroid treatment, advanced tumor pathology, Parkinson's disease or inability to comply with the rehabilitation program.

3.2 Characteristics of the patients

A total of 27 patients (19 women and 8 men) were included in the study with an average age 75 years (range: 58 to 87 years); 16 non-dominant and 11 on the dominant. Seven shoulders had undergone previous non-prosthetic operations: 3 arthroscopic cuff repairs, 2 arthroscopic acromioclavicular joint resections, 1 arthroscopic acromioplasty and 1 osteosynthesis for a proximal humerus fracture.

Massive rotator cuff tears were found in 8 patients, massive rotator cuff tears with osteoarthritis in 8 and true CTA in 11 patients.

Of the 27 implanted prostheses, 8 stems were cemented and 19 were press-fitted. Bone grafting using resected humeral head was used in 3 cases.

3.3 Characteristics of the study

The study was constructed as a prospective randomized trial with a single-blind control procedure; as the installation of the patient was identical for the two groups, the approach was

determined by drawing a lot by a third party who did not know the clinical history of the patient immediately before incision.

In order to analyze the results of this study, several outcome measures have been compared between approaches. Firstly the Constant Score (CS) has been utilized because it is considered to be a complete tool to assess shoulder functionality.[28,29] Other functional clinical outcomes comprehended patient reported outcome scores such as subjective shoulder value (SSV), patient's satisfaction and specific shoulder function (SSF). The range of motion (ROM) was measured with a handheld goniometer. Radiological outcome consisted of the analysis of prosthetic positioning with preoperative comparison and in assessment of the notching grade on conventional radiographs. Lastly, the complications were documented.

3.4 Ethics of the study

All patients gave their written informed consent in writing to the terms and conditions and were notified that their data would be anonymized and used for research purpose exclusively in this study. They were also informed about the risks and benefits of RTSA and they agreed to participate to the regular controls.

This study respects the guidelines of *Good Clinical Practice* and the regulations of the Swiss law of human research and is legitimate by the ethical commission of the canton Zürich (Kantonale Ethik-Kommission, KEK), approval number EK-37/2007.

3.5 Surgical technique

An antibiotic prophylaxis was given 20 minutes before incision. General anesthesia with a concomitant interscalene bloc was used. The patient was installed in the beach chair position. After desinfection, the upper limb was draped free to be able to mobilize the limb during the procedure. The Anatomical Reverse® prosthesis (Zimmer Warsaw, IN, USA) was used in all cases and the surgeries were performed by or under direct supervision of two senior surgeons (C.G., B.J.).

3.5.1 Deltopectoral approach

The skin incision reaches from lateral to the coracoid process to the insertion of the deltoid muscle at the deltoid tuberosity.[22] The cephalic vein is identified and retracted laterally and a blunt dissection of the subdeltoid space is performed. The axillary nerve lies 3-7 cm below

the lateral acromion, in the deep surface of the deltoid muscle and is protected throughout the procedure.[5,17,22]

The deltoid muscle is mobilized and retracted laterally. Rarely, the superiormost part of the insertion of the pectoralis major is released in order to provide sufficient exposure. The conjoint tendon is medially retracted and the biceps tendon is tenotomized or tenodesed (according to the surgeon's preference) at its origin.[17,30]

The arm of the patient is adducted and progressively externally rotated and the subscapularis tendon is then released either by peeling or osteotomizing the lesser tuberosity. The capsule is released at the inferomedial part of the humerus.[17,22]

Osteophytes are debrided from the humeral head and neck and with the placement of two retractors inside the glenohumeral joint, an anterior dislocation of the arm is achieved.[22,30]

The humeral neck cut is made with a cutting guide usually at 10-30° of retroversion and an adapted cut-inclination between 135° or 155°.[17,22,30]

After reaming the humeral canal with a T-handle, a trial stem is inserted and left in place. Then preparation of the glenoid is initiated, paying particular attention to the axillary nerve. A circumferential capsular release and debridement of the periglenoidal osteophytes allow for a good exposure of the glenoid fossa.[22,30]

Preoperative imaging allows to determine whether a bone graft or a more inferior/posterior reaming of the glenoid surface, as in rotator CTA with Sirveaux grades E2/E3/E4 or osteoarthtitis with glenoid erosion grades Walch B2 to C are necessary.[17,31–34]

A guide pin is then introduced in the central glenoid serving to guide glenoid surface reaming.[17] The definitive glenoid baseplate is then implanted and secured with two locking screws. The size of the glenosphere is chosen according to the amount of soft tissue tension desired, the bone quality and the patient's size.[17,22]

Once the trial components are in place, the surgeon reduces the artificial joint and assesses it for ROM, stability, and soft tissue tension. If the results are satisfactory, the definitive components are implanted, with or without cementation of the humeral stem according to the quality of press-fit obtained with the non-cemented version.

Joint stability is assessed by testing abduction, extension, and internal rotation (position of greatest instability). Thereafter the subscapularis tendon is repaired to the lesser tuberosity and the wound is closed over two suction drains. A sterile bandage is applied and the arm is placed in a sling.[13,17,30]

3.5.2 Superolateral approach

The skin incision begins at the antero-lateral corner of the acromion and follows the fiber orientation of the deltoid towards its humeral insertion for 5 to 10cm.[9]

Under the skin surface, the deltoid dissection is performed between its anterolateral (Fick Zone II) and medial (Fick Zone III) parts and follows the direction of the skin incision, but no longer than 4 cm inferiorly from the lateral aspect of the acromion (in order to protect the axillary nerve). The deltoid muscle is then split and partly detached form the lateral acromion.[9]

The incision of the subacromial bursa allows exposure of the humeral head. External rotation of the arm allows assessing the state of the rotator interval, the subscapularis, suraspinatus, and the biceps while internal rotation allows visualizing the infraspinatus and the teres minor. In large rotator cuff tears, the tendons of these muscles are absent or retracted.[9,10,14] The long head of the biceps tendon is tenotomized and left alone or tenodesed in the bicipital groove.[9,22]

With external rotation of the limb and traction of the humerus, an anterosuperior dislocation of the head can be achieved, allowing the cutting guide for the humeral head to be inserted. The degree of retroversion of the cut refers to the axis of the humeral epicondyles and is between 10 and 30° as in the DP cases.[9,17]

The medullary cavity of the humerus is enlarged with a T-handle and afterwards (after a trial stem is set) the reaming of the humeral neck is started. This allows to fit the epiphyseal stem of the prosthesis.[9]

As the trial humeral stem is in place, an anterior glenoid neck retractor is placed under its inferior labrum, in order to allows a clear visualization of the glenoid. At the same time the release of the long head of the triceps can be performed.[9]

The excision of the labrum and an extensive periglenoidal capsulotomy is done, along with the removal of the peripheral osteophytes. Smoothing the glenoid surface allows for a good and solid base for the glenoid component implantation. If this is not sufficiently achieved, a bone graft can be performed as with the DP approach.[17,31–34]

After the reaming is complete and sufficient, the metaglene (glenoid baseplate component) is inserted, along with the attachment of the trial glenosphere and stability assessment. If instability persists, it can be improved by changing the height of the prosthesis.[9,17]

Once the stability of the artificial joint is acceptable, the definitive glenosphere is implanted and the definitive humeral stem is inserted into the humeral shaft again with or without cement according to the obtained stability with press-fitting alone.[9,17]
The tendon of the subscapularis is reattached. Two deep drains are left in place in order to avoid postoperative hematoma. The deltoid is reattached to the acromion using transosseous sutures followed by usual wound closure.

3.6 Postoperative phase

The drains are left in place for 24 to 48 hours. A sling is used immediately postoperatively and removed after 4 to 6 weeks. The sterile bandage rests in place for 2 weeks. Interscalene anesthesia maintained using a catheter for 24 to 48 hours. The hospital stay is normally between 3 and 7 days, depending on the pain and the mobilization with physiotherapy.
Passive and active-assisted exercises are immediately started and after 6 weeks, active mobilization of the shoulder is allowed without resistance.
After 3 months, the use of the arm is no longer restricted. Exercises are progressively carried out against resistance until the full load capacity is achieved.
At every follow-up (FU) control, the ROM is assessed in a standardized fashion, along with pain assessment with a visual analog scale (VAS) and the CS measure. Additionally, conventional antero-posterior, xillary lateral and true lateral radiographs of the shoulder are taken at 6 weeks, 3 months, 1 and 2 years of the FU phase.

3.7 Clinical evaluation

3.7.1 Preoperatively

In the preoperative phase, assessment of the shoulder function is performed by physical examination and scoring according to the respective outcome measurement tools.
The CS is assessed and can range from 0 to 100 points and sums up different categories: “Pain” (0 to 15 points), “Activity” (0 to 20 points), “Mobility” (0 to 40 points) and “Strength” (0 to 25 points).
“Pain” is assessed with the help of a VAS where 0 corresponds to an unbearable painful situation and 15 to a completely pain free situation.

"Activity" is graded by the capacity of working the daily tasks (0 to 4 points), performing hobbies or sportive activities (0 to 4 points), pain free sleeping at night (0 to 2 points) and pain free hand tasks in different positions.[29]

"Mobility" refers always to active, pain free mobility and is divided in subcategories, namely forward flexion, abduction, functional ER and functional internal rotation (IR). For each movement a maximum of 10 points can be attributed and for forward flexion and abduction the following scores are attributed: 0-30° 0 points, 31-60° 2 points, 61-90° 4 points, 91-120° 6 points, 121-150° 8 points and 151-180° 10 points.[29] Functional ER allots 2 points for each of 5 separate unassisted function: hand to the back of the head with the elbow forward, hand to the back of the head with the elbow back, hand to the top of the head with the elbow forward, hand to the top of the head with the elbow back and full elevation. Functional IR scoring consists of allotting 0 points to thumb reaching the lateral aspects of the thigh, 2 points behind the buttock, 4 points to the sacroiliac joint, 6 points to the level of the waist, 8 points to the twelfth thoracic vertebra and 10 points to the interscapular level.[29]

"Strength" is assessed with the help of an Isobex® dynamometer (Cursor AG, Bern, Switzerland) designed for testing the strength with the CS. In the device each point corresponds to a pound (0.45kg) of tension up to a maximum of 25 pounds (11.25kg), 1 point is attributed per pound of generated tension. Strength measurement is performed with the arm extended in the elbow, pulling straight upward at 90° of abduction; if this position could not be reached, the strength is considered 0.[13,29]

For comparison with a normal shoulder, the adjusted or relative CS is calculated: this consists of the CS-percentage of the affected shoulder in relation to a normal age- and gender matched CS.[29] For the SSV the patient subjectively assesses the value of his shoulder in percent of a completely normal shoulder, i.e. he or she indicates that the subjective value of the affected shoulder is 30% of that of a completely normal shoulder.

External rotation (ER) was also measured in degrees with the arm at the side and the elbow flexed to 90° degrees.

Lastly, a questionnaire about the SSF (hand to head, hand to mouth, hand to the shoulder, hygiene possibility, dressing capacity, overhead work possibility) and a form to evaluate the patient's satisfaction (poor, fair, good, excellent) has been used.

3.7.2 Postoperatively

The assessment of shoulder function in the postoperative phase followed the above outline at several FU times:

- Discharge: painless passive ROM and nerve function;
- 6 weeks: passive ROM, pain (VAS), nerve function and complications;
- 3 months: active ROM, pain (VAS) and complications;
- 1 year: active painless ROM, pain (VAS), complications, CS, SSV, SSF and patients' satisfaction;
- 2 years: active painless ROM, pain (VAS), complications, CS, SSV, SSF and patients' satisfaction.

To determine the improvement of active mobility, photographs documenting ROM were made at each step (pre- and postoperatively) for every patient.

3.8 Radiological Evaluation

3.8.1 Preoperatively

In the preoperative phase, the assessment of the shoulder was made with CT images and conventional radiographies (CR) in the true anteroposterior, axillary lateral and true lateral (Neer's Y-view) projections. The radiological analysis of the preoperative images followed accepted scoring systems to classify changes related to rotator cuff tears and glenoid morphology in CTA.

- Hamada classification of cuff tear induced shoulder changes: Six stages of changes are distinguished on conventional antero-posterior radiographs: Grade I corresponds to an acromiohumeral interval (AHI) greater than 6 mm, grade II to an AHI less than 7 mm, grade III to an AHI less than 7mm with acetabulization of the acromion (the acromion undersurface deforms itself to a concave morphology), grade IVA to an AHI less than 7 mm with glenohumeral arthritis without acetabulization, grade IVB to an AHI less than 7 mm with glenohumeral arthtitis and acetabulization, grade V to an AHI less than 7 mm with humeral head collapse and osteonecrosis.[12,35,36]
- Sirveaux classification assesses cuff tear induced vertical glenoid erosion: It distinguishes 4 erosion types: E0 corresponds to a upward migration of the humeral head without erosion of the glenoid, E1 to a concentric erosion of the glenoid, E2 of a superior glenoid erosion and E3 to the previous grade extended toward the inferior part of the glenoid.[12,25,31]
- Walch's classification of "horizontal" glenoid changes in osteoarthritis. It is assessed on CT images and composed of 3 types. Type A corresponds to symmetrical minor (A1) or major (A2) erosion of the glenoid without subluxation of the humeral head. Type B corresponds to asymmetrical posterior glenoid erosion due to the subluxation of the

humeral head with narrowing of the posterior joint space (B1) or marked posterior erosion with biconcave glenoid morphology (B2). Type C is defined by glenoid-retroversion of more than 25°, regardless of erosion.[12,32,33]

Glenoid retroversion has been defined on CT images as the angle between the line perpendicular to the axis of the scapula and the line tangent to the edges of the glenoid fossa according to Friedman et al.[37]

- The Goutailler classification assesses fatty infiltration of the rotator cuff muscles. This is performed on non-fat saturated oblique sagittal T1 sequences or CT images. It distinguished 5 grades: grade 0 corresponds to a completely normal muscle, grade 1 to the presence of some fatty streaks in the muscle, grade 2 to less fat than muscle, grade 3 to an amount of fat which is equal to muscle mass and grade 4 with more fat than muscle.[38]

Additionally, on all antero-posterior CRs, glenoid inclination relative to the supraspinatus fossa was assessed according to Mauer et al. using the angle β. This is the angle formed between the line connecting the uppermost and the lowermost points of the glenoid surface and the floor of the supraspinatus fossa.[39]

3.8.2 Postoperatively

In the postoperative phase, the shoulder was assessed with antero-posterior CR immediately after surgery, and at the 6-week, 3-month, 1- and 2-year FUs.

The radiological analysis of postoperative images included tracking of 2 parameters.

- Notching assessed according to Nérot-Sirveaux on antero-posterior CR. Grade 1 corresponds to an erosion contained within the inferior part of the scapular neck, grade 2 to an erosion of the scapular neck to the inferior fixation screw of the glenoid component, grade 3 to an erosion and bone loss over the inferior fixation screw, and grade 4 to an erosion with progression to the undersurface of the baseplate.[25,40] As notching is an unique complication of RTSA and as its recurrence depends mainly to intra- and postoperative processes, preoperative data were not statistically analyzed.[11,30,41,42]
- Comparison of the glenoid inclination of the angle β between the preoperative bony glenoid and the postoperative glenoid component.[39]

3.9 Statistical analysis

The statistical analysis was carried out using SPSS v23. Two-sided p-value were considered significant if smaller than 0.01 and collected data were considered as ordinal; therefore the

performed tests rely on non-parametric data, because they do not belong to a normal distribution.

The comparison between the approaches (based on secondary outcomes as CS, ROM and complications' rate) was made using the Mann-Whitney test for independent samples by calculating the median and the interquartile range (IQR) with quartiles.

FU values have been compared to preoperative values using the Wilcoxon signed ranks test for matched or dependent samples. Median and IQR with quartiles have been calculated. All statistical analyses of the clinical outcome (with complication rates) rely on the data collected at the first and second year of FU. Statistics of radiological outcome takes into consideration also the 6-week and the 3-month FU.

4 Results

4.1 Structural parameters preoperatively

The structural parameters of the shoulders operated in the 2 groups are depicted in Table 1:

Table 1: preoperative classification of cuff tear arthropathy* and glenoid morphology for DP and SL approach (number / percentage), n=27**

		DP	SL	DP + SL
Hamada	I (n /%)	3 / 21.4	6 / 46.2	9 / 33.3
	II (n /%)	5 / 35.7	3 / 23.1	8 / 29.6
	III (n /%)	1 / 7.1	2 / 15.4	3 / 11.1
	IVA (n /%)	1 / 7.1	1 / 7.7	2 / 7.4
	IVB (n /%)	3 / 21.4	0 / 0.0	3 / 11.1
	V (n /%)	1 / 7.1	1 / 7.7	2 / 7.4
Sirveaux	E0 (n /%)	10 / 71.4	8 / 61.5	18 / 66.7
	E1 (n /%)	4 / 28.6	3 / 23.1	7 / 25.9
	E2 (n /%)	0 / 0.0	2 / 15.4	2 / 7.4
	E3 (n /%)	0 / 0.0	0 / 0.0	0 / 0.0
Walch	A1 (n /%)	9 / 64.3	8 / 61.5	17 / 63.0
	A2 (n /%)	3 / 21.4	2 / 15.4	5 / 18.5
	B1 (n /%)	1 / 7.1	3 / 23.1	4 / 14.8
	B2 (n /%)	1 / 7.1	0 / 0.0	1 /3.7
	C (n /%)	0 / 0.0	0 / 0.0	0 / 0.0

DP = deltopectoral approach, SL = superolateral approach, n = number of patients, *assessed with Hamada classification, **assessed with Sirveaux and Walch classifications

Table 1 reports the clinical classification of CTA according to Hamada, Sirveaux and Walch for the 27 patients that underwent RTSA in this study.

A total of 27 patients were initially included; 14 underwent the surgery with the DP approach and 13 with the SL approach. At 1 year FU, 22 patients were included for the statistical evaluation, as each group had 11 subjects. At 2 years FU, the cohort consisted of 21, 11 in the DP group and 10 in the SL group.

4.2 Losses to follow-up

For each group 3 definitive and 1 temporary losses to FU were reported; in the DP group 3 patients suffered from glenoid loosening (2 within the first year and 1 within the second year) and 1 patient was temporarily unable to participate to the first annual FU. In the SL 1 patient suffered from a intraoperative humeral and postoperative glenoid fracture within the first year, 2 patients refused to participate to the second annual FU and 1 refused to participate only to the first annual FU.

4.3 Functional clinical outcome

4.3.1 Comparison of pre- and postoperative functional outcome

Table 2: Outcomes according to the CS preoperatively, at 1° and at 2° year of FU (median, IQR with quartiles), n=27

	Preoperative	1year postoperative	Gain	P-value	2years postoperative	Gain	P-value
Pain (0-15 points)	4.1 (1.9 to 5.5)	14.5 (13.2 to 15.0)	10.4	<0.01	14.5 (12.3 to 14.9)	10.4	<0.01
Activity (0-20 points)	9.9 (8.3 to 11.8)	19.1 (17.8 to 19.1)	9.2	<0.01	19.1 (17.9 to 19.7)	9.2	<0.01
Mobility (0-40 points)	18.0 (12.0 to 22.8)	29.4 (25.6 to 33.2)	11.4	<0.01	29.6 (25.2 to 33.5)	11.6	<0.01
Strength (0-25 points)	0.5 (0.0 to 2.1)	3.5 (1.1 to 5.6)	3.0	<0.01	4.0 (1.8 to 6.7)	3.5	<0.01
Total CS (0-100 points)	32.8 (26.5 to 38.0)	66.3 (63.0 to 71.7)	33.5	<0.01	69.0 (58.8 to 73.8)	36.2	<0.01
Adjusted CS (%)	48.5 (36.3 to 54.3)	91.0 (77.0 to 98.6)	42.5	<0.01	87.0 (80.8 to 98.4)	38.5	<0.01
SSV (%)	25.0 (11.5 to 39.4)	82.0 (76.1 to 90.0)	57.0	<0.01	78.8 (69.4 to 94.2)	53.8	<0.01

n = number of patients

Table 2 shows the pre- and postoperative values of the functional outcome, here presented with CS, adjusted CS and SSV. The gain of function with the reverse prosthesis implantation is statistically significant ($P < 0.01$) for all the categories of the CS, adjusted CS as well for the SSV.

4.3.2 Comparison of pre- and postoperative functional outcome for both approaches

Table 3: Clinical outcomes according to CS for DP and SL approach preoperatively, at 1° and 2° year of FU (median, IQR with quartiles), n=27

	preoperative		1year postoperative		2years postoperative	
	DP	SL	DP	SL	DP	SL
Pain (0-15 points)	4.2 (2.0 to 5.3)	4.0 (1.8 to 6.3)	14.3 (13.1 to 14.8)	14.3 (13.1 to 15.0)	13.7 (10.3 to 15.0)	14.6 (14.0 to 15.0)
P-value			<0.01	<0.01	<0.01	<0.01
Activity (0-20 points)	9.8 (8.3 to 11.8)	10.0 (7.5 to 11.9)	19.0 (17.3 to 20.0)	19.2 (18.1 to 20.0)	19.0 (17.3 to 20.0)	19.3 (18.3 to 20.0)
P-value			<0.01	<0.01	<0.01	<0.01
Mobility (0-40 points)	19.5 (12.0 to 23.7)	16.0 (11.5 to 20.5)	29.2 (25.0 to 31.8)	30.0 (26.3 to 34.3)	29.3 (23.7 to 33.0)	30.0 (26.5 to 34.0)
P-value			<0.01	<0.01	<0.01	<0.01
Strength (0-25 points)	0.9 (0.0 to 3.0)	0.5 (0.1 to 2.1)	3.0 (0.9 to 5.5)	4.0 (1.5 to 5.8)	5.2 (2.0 to 8.6)	3.3 (2.0 to 6.0)
P-value			0.446	0.018	0.096	0.027
Total CS (0-100 points)	33.7 (29.0 to 39.7)	31.0 (25.5 to 34.5)	66.3 (63.3 to 69.5)	66.0 (62.3 to 73.8)	69.0 (58.3 to 74.5)	66.5 (61.0 to 73.0)
P-value			<0.01	<0.01	<0.01	<0.01
Adjusted CS (%)	49.7 (45.0 to 56.8)	42.0 (35.8 to 50.3)	95.0 (77.7 to 99.1)	89.0 (78.9 to 96.9)	89.0 (76.8 to 99.4)	86.3 (79.5 to 93.0)
P-value			<0.01	<0.01	<0.01	<0.01
SSV (%)	28.3 (16.0 to 43.3)	20.0 (7.0 to 36.3)	83.0 (75.8 to 92.5)	81.0 (75.5 to 87.5)	77.5 (66.7 to 93.1)	80.0 (70.0 to 95.0)
P-value			<0.01	<0.01	<0.01	<0.01

DP = deltopectoral approach, SL = superolateral approach, n = number of patients

Table 3 completes the results shown in Table 2, as it compares the two different groups in the postoperative FUs.

The two approaches exhibit a statistically significant improvement ($P < 0.01$) in all the CS categories except for the "Strength" category ($P > 0.01$).

In addition to the CS and the SSV, also the pre- and postoperative grade of satisfaction has been evaluated, as well as the SSF.

Table 4: Preoperative patient's satisfaction and postoperative comparison between DP and SL approach at 1° and 2° year of FU (number of patients / percentage), n=27

	preoperative		1year postoperative		2years postoperative	
	DP	SL	DP	SL	DP	SL
Poor (n / %)	14 / 100.0	7 / 53.8	0 / 0.0	0 / 0.0	0 / 0.0	0 / 0.0
Fair (n / %)	0 / 0.0	6 / 46.2	1 / 9.1	0 / 0.0	1 / 9.1	0 / 0.0
Good (n / %)	0 / 0.0	0 / 0.0	1 / 9.1	2 / 18.2	3 / 27.3	2 / 20.0
Excellent (n / %)	0 / 0.0	0 / 0.0	9 / 81.8	9 / 81.8	7 / 63.6	8 / 80.0
Total (n / %)	14 / 100.0	13 / 100.0	11 / 100.0	11 / 100.0	11 / 100.0	10 / 100.0
P-value*			0.922		0.372	

DP = deltopectoral approach, SL = superolateral approach, n = number of patients

Table 4 shows the pre- and postoperative patient's satisfaction and an overall improvement of the two groups is observed regardless from the chosen approach ($P = 0.922$ at 1° year of FU and $P = 0.372$ at 2° year).

Table 5: Preoperative shoulder specific function and postoperative comparison between DP and SL approach at 1° and 2° year of FU (number of patients / percentage of patients)

	preoperative, n=27		1year postoperative, n=22		2years postoperative, n=21	
	DP	SL	DP	SL	DP	SL
Hand to Head (n / %)	14 / 100.0	11 / 84.6	11 / 100.0	11 / 100.0	11 / 100.0	10 / 100.0
P-value			1.000		1.000	
Hand to Mouth (n / %)	11 / 78.6	8 / 61.5	11 / 100.0	11 / 100.0	11 / 100.0	10 / 100.0
P-value			1.000		1.000	
Hand to other Shoulder (n / %)	10 / 71.4	5 / 38.5	10 / 90.9	11 / 100.0	11 / 100.0	10 / 100.0
P-value			0.317		1.000	
Hygiene capacity (n / %)	14 / 100.0	11 / 84.6	11 / 100.0	11 / 100.0	10 / 90.9	10 / 100.0
P-value			1.000		0.340	
Dressing capacity (n / %)	13 / 92.9	9 / 69.2	11 / 100.0	11 / 100.0	11 / 100.0	10 / 100.0
P-value			1.000		1.000	
Overhead work capacity (n / %)	0 / 0.0	0 / 0.0	11 / 100.0	8 / 72.7	8 / 72.7	8 / 80.0
P-value			0.300		0.809	

DP = deltopectoral approach, SL = superolateral approach, *P-value < 0.01 represents statistical significant difference between approaches

Table 5 shows the pre- and postoperative SSF and the usability of the shoulder improved for the most common tasks in everyday activities. The most improved category is the overhead work capacity, showing a two-year FU improvement of 72.7% for the DP and of 80.0% for the SL group. The analysis showed no statistical difference between the approaches in the domain of SSF ($P > 0.01$).

4.3.3 Comparison of the postoperative functional outcome between approaches

Table 6: Comparison of outcomes (according to CS) between DP and SL approach at 1° and 2° year of FU (median, IQR with quartiles), n=27

	1year postoperative			2years postoperative		
	DP	SL	P-value	DP	SL	P-value
Pain (0-15 points)	14.3 (13.1 to 14.8)	14.3 (13.1 to 15.0)	0.813	13.7 (10.3 to 15.0)	14.6 (14.0 to 15.0)	0.372
Activity (0-20 points)	19.0 (17.3 to 20.0)	19.2 (18.1 to 20.0)	0.819	19.0 (17.3 to 20.0)	19.3 (18.3 to 20.0)	0.564
Mobility (0-40 points)	29.2 (25.0 to 31.8)	30.0 (26.3 to 34.3)	0.621	29.3 (23.7 to 33.0)	30.0 (26.5 to 34.0)	0.538
Strength (0-25 points)	3.0 (0.9 to 5.5)	4.0 (1.5 to 5.8)	0.508	5.2 (2.0 to 8.6)	3.3 (2.0 to 6.0)	0.431
Total CS (0-100 points)	66.3 (63.3 to 69.5)	66.0 (62.3 to 73.8)	0.624	69.0 (58.3 to 74.5)	66.5 (61.0 to 73.0)	0.806
Adjusted CS (%)	95.0 (77.7 to 99.1)	89.0 (78.9 to 96.9)	0.232	89.0 (76.8 to 99.4)	86.3 (79.5 to 93.0)	0.650
SSV (%)	83.0 (75.8 to 92.5)	81.0 (75.5 to 87.5)	0.239	77.5 (66.7 to 93.1)	80.0 (70.0 to 95.0)	0.556

DP = deltopectoral approach, SL = superolateral approach, n = number of patients

Table 6 shows the comparison between values of CS, adjusted CS and SSV for DP and SL group at the first and second year of FU.

No statistical difference between the two approaches in the RTSA was observed for analyzed parameter in this range of time ($P > 0.01$).

4.4 Shoulder range of motion

4.4.1 Comparison of pre- and postoperative ROM for both approaches

Table 7: Shoulder ROM for DP and SL approach preoperatively and at 1° and 2° postoperative year (median, IQR with quartiles), n=27

	preoperative		1year postoperative		2years postoperative	
	DP	SL	DP	SL	DP	SL
Flexion (0-180°)	85.2 (55.5 to 110.0)	66.7 (47.5 to 88.3)	125.0 (113.8 to 143.8)	126.7 (108.3 to 147.5)	135.0 (111.3 to 145.8)	132.5 (114.0 to 150.0)
P-value			<0.01	<0.01	<0.01	<0.01
Abduction (0-180°)	87.5 (45.0 to 103.3)	65.0 (43.8 to 76.3)	122.5 (109.2 to 136.1)	108.0 (95.0 to 137.0)	116.7 (83.8 to 130.6)	133.3 (115.0 to 147.5)
P-value			<0.01	<0.01	0.074	<0.01
Functional ER (0-10pt)	6.0 (1.6 to 8.3)	3.3 (0.9 to 5.1)	9.0 (7.8 to 10.0)	9.3 (8.3 to 10.0)	9.0 (7.4 to 10.0)	9.3 (8.2 to 10.0)
P-value			<0.01	<0.01	<0.01	<0.01
Functional IR (0-10pt)	5.1 (3.3 to 6.8)	6.7 (3.3 to 9.5)	5.7 (3.8 to 7.8)	5.6 (3.0 to 7.5)	6.7 (4.3 to 8.6)	6.0 (2.7 to 8.0)
P-value			0.271	0.121	0.107	0.161
Ext. Rotation (0-90°)	25.0 (18.0 to 40.0)	41.3 (17.5 to 48.5)	40.0 (26.7 to 46.9)	40.0 (22.5 to 46.9)	30.0 (15.0 to 45.0)	28.0 (12.5 to 36.0)
P-value			0.402	0.398	0.474	0.256

DP = deltopectoral approach, SL = superolateral approach, n = number of patients

In Table 7 are listed the preoperative and postoperative values for active shoulder ROM.
There are two subcategories that did not show statistically significant results; the first is the functional IR ($P > 0.01$) and the second is the pure ER ($P > 0.01$).

4.4.2 Comparison of postoperative shoulder ROM between approaches

Table 8: Comparison of the ROM between DP and SL approach at 1° and 2° year of FU (median, IQR with quartiles), n=27

	1year postoperative			2years postoperative		
	DP	SL	P-value	DP	SL	P-value
Flexion (0-180°)	125.0 (113.8 to 143.8)	126.7 (108.3 to 147.5)	0.712	135.0 (111.3 to 145.8)	132.5 (114.0 to 150.0)	0.901
Abduction (0-180°)	122.5 (109.2 to 136.1)	108.0 (95.0 to 137.0)	0.386	116.7 (83.8 to 130.6)	133.3 (115.0 to 147.5)	0.247
Functional ER (0-10pt)	9.0 (7.8 to 10.0)	9.3 (8.3 to 10.0)	0.665	9.0 (7.4 to 10.0)	9.3 (8.2 to 10.0)	0.517
Functional IR (0-10pt)	5.7 (3.8 to 7.8)	5.6 (3.0 to 7.5)	0.560	6.7 (4.3 to 8.6)	6.0 (2.7 to 8.0)	0.707
ER (0-90°)	40.0 (26.7 to 46.9)	40.0 (22.5 to 46.9)	0.771	30.0 (15.0 to 45.0)	28.0 (12.5 to 36.0)	0.966

DP = deltopectoral approach, SL = superolateral approach, n = number of patients

Table 8 shows the comparison between the DP and the SL approach for the postoperative ROM at the first and second year of FU.
There is no statistical difference between the approaches for the shoulder ROM in the observed time period ($P > 0.01$).

4.5 Radiological outcome

4.5.1 Glenoid inclination

Table 9: Preoperative glenoid inclination* and postoperative comparison between DP and SL approach at 1° and 2° year of FU (median value), n=27

	Preoperative		6weeks postoperative		3months postoperative		1year postoperative		2years postoperative	
	DP	SL	DP	SL	DP	SL	DP	SL	DP	SL
Glenoid inclination	74.6	78.0	86.0	84.0	84.7	83.8	85.4	87.0	83.9	85.7
P-value**			0.702		0.940		0.379		0.425	

DP = deltopectoral approach, SL = superolateral approach, n = number of patients, *inclination assessed with angle β in the scapular plane, **P-value < 0.01 represents statistical significant difference between approaches

Table 9 shows the same value reported in Figure 13 with the postoperative comparison between the groups. There is no statistical difference between them ($P > 0.01$) at all FU controls.
Preoperative median value of β-angle was 74.6° for the DP group and 78.0° for the SL group. At the second year after RTSA the median value of β-angle for the DP approach was 83.9° with a gain of 9.3° compared to preoperative value and 85.7° with 7.7° of gain for the SL group.

4.5.2 Notching grade

Table 10: Postoperative comparison of notching grade between DP and SL approach at 1° and 2° year of FU (median value, IQR with quartiles), n=23

	6weeks postoperative		3months postoperative		1year postoperative		2years postoperative	
	DP	SL	DP	SL	DP	SL	DP	SL
Notching grade	0	1	0	1	1	1	1	2
IQR with quartiles	0 to 1	0 to 1	0 to 1	0 to 1	0 to 2	1 to 2	0 to 2	1 to 2
P-value*	0.286		0.067		0.601		0.648	

DP = deltopectoral approach, SL = superolateral approach, n = number of patients, *P-value < 0.01 represents statistical significant difference between approaches

Table 10 reports the median value of the notching grade between the approaches. There are no statistical differences at all FU times (P > 0.01).

For the DP group, the analysis showed that the median of inferior notching grade has been 0 at the 6-week control and grade 1 for the other controls (3-month, 1-year and 2-year), whereas in the SL group, the median of the notching grade has been 1 at the first three controls (6-week, 3-months, 1-year) and 2 on the second year of FU.

Table 11: Notching according to Nérot-Sirveaux* at 2° year of FU (number of patients / percentage of patients), n=23

	DP	SL	DP + SL
Notching grade 0 (n / %)	3 / 27.3	2 / 16.6	5 / 21.7
P-value**	0.547		
Notching grade 1 (n / %)	3 / 27.3	6 / 50.0	9 / 39.1
P-value	0.275		
Notching grade 2 (n / %)	4 / 36.4	4 / 33.3	8 / 34.8
P-value	0.881		
Notching grade 3 (n / %)	1 / 9.1	0 / 0.0	1 / 4.3
P-value	0.296		
Notching grade 4 (n / %)	0 / 0.0	0 / 0.0	0 / 0.0
P-value	1.000		

DP = deltopectoral approach, SL = superolateral approach, *Complications with prosthesis revision have been excluded, **P-value < 0.01 represents statistical differencee between approaches, n = number of patients

Table 11 reports the inferior notching grade according to the classification of Nérot-Sirveaux at the second year of FU for the two groups and for the entire cohort. Patients who had major complications have been excluded, as it was not always possible to classify their notching grade due to fractures or dislocations of the prosthetic joint.[40,43]

Notching was found in 18 patients with a frequency of 78.3%. Of this complication, in 17 cases (94.4%) the grade was 1 or 2 and only in one case (5.6%) of grade 3.

There is no significant difference in the notching grade between the two approaches at the second year of FU. None of the P-values rest in the significance interval: Grade 0 (P = 0.547), grade 1 (P = 0.275), grade 2 (P = 0.881), grade 3 (P = 0.296) and grade 4 (P = 1.000).

4.6 Complications

The DP group shows 3 complications that led to a revision of the prosthesis and 2 other complications. Prosthetic revision was necessary for a cranial loosening of the glenoid component (with change of glenosphere), a rupture of the inferior screw with change of glenoid and humeral components and 1 more glenoid loosening with subacromial impingement associated with pain that led to a revision of both prosthetic components. Other complications included a postoperative pulmonary embolism and a hematoma; both were treated successfully and resolved without further surgery.

The SL group exhibits 2 complications with subsequently prosthetic revision and 2 other substantial complications. A single patient sustained both complications that needed a prosthetic revision. Primary an intraoperative humeral stem fracture occurred and was successfully treated with suture cerclages. Additionally, in the same patient a periprosthetic glenoid fracture and a radial palsy were identified postoperatively. Both complications were treated converting the reverse shoulder joint into a hemiprosthesis with concomitant neurolysis of the radial nerve with full subsequent recovery.

Table 12: Comparison of clinical complications up to the 2° year of FU between approaches (number of patients / percentage of patients) n=27

			DP	SL	DP + SL	P-value
Major complications	With revision	Glenoid loosening with secondary joint dislocation (n / %)	2 / 14.3	0 / 0.0	2 / 7.4	0.134
		Glenoid loosening with subacromial impingement (n / %)	1 / 7.2	0 / 0.0	1 / 3.7	0.335
		Glenoid fracture (n / %)	0 / 0.0	1 / 7.7	1 / 3.7	0.299
		N.radialis lesion (n / %)	0 / 0.0	1 / 7.7	1 / 3.7	0.299
	Without revision	Scapula fracture (n / %)	1 / 7.2	0 / 0.0	1 / 3.7	0.335
		Humerus fracture (n / %)	0 / 0.0	1 / 7.7	1 / 3.7	0.299
		N.axillaris lesion (n / %)	0 / 0.0	1 / 7.7	1 / 3.7	0.299
Minor complications		Pulmonary embolism (n / %)	1 / 7.2	0 / 0.0	1 / 3.7	0.335
		Hematoma (n / %)	1 / 7.2	0 / 0.0	1 / 3.7	0.335
Total		Major complications (n / %)	4 / 28.6	4 / 30.8	8 / 29.6	0.902
		Minor complications (n / %)	2 / 14.3	0 / 0.0	2 / 7.4	0.165
		Glenoid loosening (n / %)	3 / 21.4	0 / 0.0	3 / 11.1	0.082
		All complications (n / %)	6 / 42.9	4 / 30.8	10 / 37.0	0.524
		Needing revision (n / %)	3 / 21.4	2 / 15.4	5 / 18.5	0.593

DP = deltopectoral approach, SL = superolateral approach, n = number of patients

In Table 12 the complications have been categorized into major complications (impairment of shoulder function with or without necessity of a revision surgery) and minor complications (less effect on the joint mechanics).

The total rate of complication was 37.0% (10 patients). In 4 patients (14.8%) the complications led to prosthetic revision.

Neither major (P = 0.902) nor minor (P = 0.165) complications were significantly more frequent in one of the two approaches. Loosening of the glenoid component occurred exclusively in the DP group, however the comparison with the other approach did not reach the level of significance (P = 0.082).

5 Discussion

5.1 Functional clinical outcome

5.1.1 Preoperative vs. postoperative

5.1.1.1 Constant Score

RTSA is a well-established treatment option for glenohumeral arthropathy with massive cuff tear and permits very successfully results, restoring shoulder function and alleviating pain.[1,4,13,15,25,40,44] Postoperative improvement of shoulder function is best represented with the CS and the results in this study are very similar to many other publications.[11,15,18,25,30,45]

After 2 years of FU (Table 3) the median value of total CS showed an improvement of 35.5 points for both groups, the median of pain score improved by 9.5 points (DP) and 10.6 points (SL) and the median of adjusted CS improved by 39.3% (DP) and 44.3% (SL). SSV improved by 49.2% (DP) and 60% (SL), reflecting the substantial subjective improvement. Postoperative improvements (Table 2-3) are very satisfactory and almost all categories exhibit statistically significant results. Only the strength category did not reach the level of statistical significance (Table 3).

The lack of significance ($P > 0.01$ for difference in the two approaches and at both years of FU) can be explained by the difficulty of measuring this parameter. If the patients could not keep the arm abducted at 90° without help, the measurement in the settings of the CS could not be properly performed, resulting in a 0 value.

In the current literature, different ways to measure strength are utilized, with or without the help of a device and with different settings methods so that it is not possible to compare our data quantitatively to the literature.[29,46,47]

In this study, strength improvement reached significance for the entire cohort. This is in line with other publications that also report similar improvements.[25,48,49] Conversely, strength improvement for the subgroups alone did not reach significance. This can be explained by the small number of patients of each subgroup.

However, questionnaires about SSF (Table 5) show that an overall usability of the shoulder, even when lifting objects, is in any case reached and is subjectively adequate.[2,11,13,15,18]

5.1.1.2 Patient's satisfaction

Subjective satisfaction improved and shows similar results than CS-improvement in this study as in various other publications.[2,11,14,16,25] It can be observed, that in the absence of complications, RTSA shows excellent outcomes even from the patient' side.[11,16,18,25]
Only 1 patient in the DP group rated its shoulder function as "poor" with a painful sensation. This case represents an exception, as ROM has only slowly recovered because of hardened periscapular musculature, which increased the painful situation. Prolonged physiotherapy has been necessary and a 6 months control has been necessary.

5.1.1.3 Specific shoulder functions

None of the patients in this study could preoperatively perform overhead tasks; this is due to the difficulty in controlling the hand in the frontal and transverse planes while trying to keep the arm elevated. The impairment of the spatial positioning is particularly difficult with combined elevation and ER pseudoparalyses, which is often seen in CTA. Thus even simple daily living activities, such as shaking hands, eating, drinking or brushing teeth can be impaired in this situation.[11,13,50]
RTSA (Table 5) can effectively restore those functions, as 72,7% (DP) and 80% (SL) of the patients could perform overhead tasks without pain after 2 years of FU. Moreover the reverse prosthetic facilitates task performing needed for activities in daily living.[13]

5.1.2 Postoperative comparison between approaches

None of the categories of the CS, nor the SSV, the patient's satisfaction or SSF showed a significant difference between the approaches (Table 5, $P > 0.01$). It may therefore be concluded that the postoperative CS does not depend on the chosen approach for RTSA.
Reviewing the literature on RTSA and the CS evolution in the first 2 years of FU, no author clearly stated a difference between used approaches.[4,11,45] However, none of these publications performed a structural analysis with the specific purpose of comparing this outcome between DP and SL approach. Approaches were not chosen with a blinding procedure, but according on patient's characteristics resulting in substantially numeric differences between groups with inevitable statistical bias. Additionally, approaches were not exactly the same in all procedures. For example, some authors utilized the anterosuperior technique as described by MacKenzie et al. (with or without resection of the acromioclavicular ligament), some other authors performed an extended acromioplasty and

some others spared this bone. Lastly, in all publications the prosthesis was from different manufactures.[4,51]

A first explanation of the insignificant difference between approaches relies on the fact that both surgical techniques are known to be successful for shoulder surgery for many years. This implies that there is substantial clinical experience with both approaches, which should prevent a high rate of complications.[5,7,9,22]

One other explanation is that these outcomes are composed by multiple factors. For example, the CS takes into consideration pain, capacity of performing all-day activities, mobility, and strength of the joint. Performance of these tasks very much depends on health status, motivation, pain forbearance and rehabilitation of the patients and thus less on the approach for RTSA, as with both an adequate positioning of the prosthesis is achieved.

Additionally, the surgeons experience seems to be a key factor in shoulder surgery, especially in the case of reverse prosthesis.[52] In this study all operations were performed by senior surgeons with many years of experience in RTSA, thus the results are successful independently of the approach. However this study is composed of short-term FU and it may be necessary to extend the observation period to have an accurate comparison of functional clinical outcomes between the approaches.

Although there is not an extensive or specific publication with statistical comparison between DP and SL approach; clinical experience and empirical knowledge point to choosing the approach in regard of intraoperative differences between them and of patient's conditions.[4,7–9] The main pros and cons of each approach are elaborated through a literature review later on (Chapter 5.6: Advantages and disadvantages of the approaches).

5.2 Shoulder range of motion

5.2.1 Preoperative vs. postoperative

Statistical analysis for both FU-years (Table 7) shows significant improvements of forward flexion ($P < 0.01$), abduction ($P < 0.01$) and functional ER ($P < 0.01$). On the other hand, functional IR and pure ER have not significantly improved ($P > 0.01$). After 2 years of FU, active forward flexion improved to 135° (111.3-145.8°) for DP approach and to 132.5° (114.0-150.0°) for SL approach. These improvements are similar to other major publications and reflect the aptitude of the reverse prosthetic joint to restore these important movements.[15,16,25,45]

Functional IR did not show significant improvement. IR, adduction, and extension compose this functional movement and the design of reverse prosthesis impairs the shoulder adduction because of components' impingement. Additionally, the medial deltoid fibers that migrate laterally lose their rotation moment, aggravating both ER and IR movements.[24]

Unexpectedly, functional ER shows a significant postoperative improvement for both approaches. This can be theoretically correlated with its combination of movements (ER, abduction and flexion). As Table 7 shows, both flexion and abduction improve significantly, thus they compensate for "pure" ER and sum up to the functional ER score.

ER did not improve significantly: from median preoperative value of 25.0° (DP) and 41.3° (SL) to 2-year postoperative values of 30.0° for DP and 28.0° for SL. The DP group shows an improvement of 5.0° and the SL group a pejoration of 13.3°. Because of the biomechanics of RTSA, this is an expected outcome and it is largely described in major publications.[1,11,23,24,27,50,53] To obviate this problem, which can impair activities of daily living (for example getting up from a chair or taking objects at the side), some solutions have been proposed. Grammont et al. proposed 3 theoretical adjustments during the surgery. First, it is possible to move the deltoid "V" insertion far forward from the deltoid tuberosity. Second, it is possible to perform an external rotational osteotomy of the humerus under the deltoid insertion. Lastly, it is also possible to increase retroversion when implanting the humeral component.[21] However, only the last option can be performed in daily surgical practice but it would have the disadvantage to decrease the range of IR so that reaching behind the back may become very difficult.[24] Another less theoretical option for postoperative ER restoring is represented by combined RTSA with a latissimus dorsi transfer. This technique is common practice in shoulder surgery and consists in transferring the latissimus dorsi tendon over the humeral head to the insertion site of the teres minor with or without concomitant teres major transfer to the lateral aspect of the humeral shaft.[26,50,53] Several publications describe the success of this surgery; for example in the study of Boileau et al. the median of ER increased by 36°.[50]

5.2.2 Postoperative comparison between approaches

As is the case of CS comparison, even the ROM does not show significant differences between the approaches for both years of observation (Table 8, $P > 0.01$). Also the literature does not document a clear difference in the ROM improvement depending on the approach.[25,45] Once again, it has to be pointed out that none of these publications have been made with the specific purpose of comparing the DP and SL approach.

The lack of significant differences between approaches in the ROM-outcome can be explained hand in hand with the functional clinical outcome. The ROM depends on multiple factors that are not strictly correlated with the chosen approach, as both allow ideal conditions for the surgery. For example it cannot be stated that (in the setting of ROM-outcome) a subscapularis cut with a DP approach represents a drawback of this technique. This is explained because of the fact that with reverse prosthesis the shoulder's biomechanics is completely twisted and its ROM does not depend on the cuff muscles.[23,24,26]

The ROM can vary with prosthesis positioning, for example with a retroverted humeral stem (in order to increase postoperative ER) and it is also possible that risk of components malpositioning can vary with the chosen approach.[24] However, the lead structures are well accessible with both and a firm knowledge of anatomy, along with modern cutting guide systems decreases the chances of a badly positioned prosthesis. It can also be stated that outcomes depend mainly on the surgeon's experience rather on the approach.

Functional clinical outcomes and ROM-outcomes are, as already stated, multifactorial and approach-independent. However, there are specific outcomes that may vary with the chosen approaches such as radiological proprieties and complications. These are analyzed and compared in the next chapters (5.3: Radiological outcome, 5.4: Complications).

5.3 Radiological outcome

5.3.1 Pre- vs. postoperative glenoid inclination compared between approaches

The native glenoid inclination depends on its anatomy but can be altered by the wear that the humeral head exerts in CTA. Postoperative glenoid inclination depends on intraoperative bone preparation and correct baseplate insertion and is a key factor for stability and notching development after RTSA.[26,27,30,42]

Median values (Table 9) of preoperative glenoid inclination are 74.6° (DP) and 78.0° (SL) while the mean of the median value for all FU is 85° (DP) and 85.1° (SL), on average there is a gain of 10.4° for the DP group and of 7.1° for the SL group.

The postoperative gain represents a more inferiorly (bigger β-angle) tilted prosthetic glenoid component with respect to the preoperative situation. The purpose of this relies on various biomechanical and clinical studies reporting less notching and less loosening incidence because of the diminution of the shear forces across the bone-baseplate interface.[17,26,41,54]

Statistical analysis (Table 9, $P > 0.01$) for this parameter showed non-statistical significant difference between the approaches. However, Lévigne et al. performed a study on scapular notching and radiological glenoid positioning and they concluded that SL approach is associated with a more superiorly tilted baseplate.[43] This is explained by the difficulty of sagittal glenoid preparation, as the strictly lateral view of the SL approach does not allow a comparison with the frontal (scapular) plane and lowers the accuracy of intraoperative inclination.

5.3.2 Postoperative notching grade compared between approaches

Notching is due to mechanical impingement between the humeral component and the inferior neck of the scapula; this produces osteolytic reaction with polyethylene wear particles liberation. In time the inferior neck will erode leaving less bone stock for properly glenoid anchorage.[24,27,42] In this study it was analyzed separately to the other complications because of the incertitude of its consequences on the clinical outcome.

Notching was found in 66.7% (DP) and in 90.9% (SL) of the cases in the second year of FU. However, statistical analysis (Table 11, Table 12, $P > 0.01$) shows that there is no significant difference of the notching grade in this study in all FU controls. One possible explanation is that the number of patients in this series is very little, as only 23 patients were compared.

Statistically, the finding in this study is in discord with other publications. However, the higher percentage of notching with the SL corresponds to the results in the literature.[4,8,26,41,43,55] For example, Lévigne et al. reported of a series of 337 RTSA (267 with DP and 70 with SL approach) at a mean 47-month FU where a higher notching incidence was correlated with the use of a SL approach.[43]

Similarly, Melis et Al. reported of 68 RTSA at a mean 9.6-year FU where inferior notching was once again correlated with SL approach.[55] This difference relies on the difficulty of positioning the glenoid baseplate. As demonstrated by Nyffeler et al. the placement of the baseplate slightly distal to the glenoid reduces notching incidence and augments abduction and adduction as well.[26] Concerning this, the access given by the SL approach is not optimal, as the axillary nerve limits the distal exposure of the scapular bone and inferior glenoid. Moreover, Sirveaux et al. as well as Delloye et al. found out that an inferior notching that extended over the inferior screw (Grade 3 or 4) significantly affected the CS.[25,26,56] Additionally, Lévigne et al. described a progression of notching grade over time that could decrease long-term results.[43]

These findings could theoretically favor the use of a DP approach for RTSA, as notching would interfere less with the postoperative functional outcomes. However, in other publications, such as the one of Werner et al. or Melis et al. with a very valid mean 9.6-year FU, notching did not correlate with lesser clinical outcomes and in most cases was low grade (grade 1 or 2).[11,55]

It can also be observed that the clinical relevance of notching grade is controversial and the literature presents in part opposite findings. However, notching has to be considered as a specific complication of RTSA and if prevention is possible, it has to be performed. The possible strategies are analyzed later on in chapter 5.4.6.

5.4 Complications

In the current literature the most common complications for primary RTSA are: 1) Hematoma, with a described risk of 5 to 12%.[11] 2) Infections (immediately postoperative but also after years) with a cumulative risk described from 2.9 to 5%.[11,57] 3) Nerve lesions (by traction movement that results in specific muscle palsy and paraesthesia) with a risk of about 4.7%). 4) Loosening of the prosthetic glenoid (risk about 5%) or of the prosthetic humeral stem (risk about 2%).[58] 5) Prosthetic joint dislocation, either primary with a multifactorial etiology or secondary to periprosthetic fractures or to component loosening with a risk about of 5%.[59] 6) Intraoperative bone fractures or postoperative fractures with a risk less than 5%.[18] Additionally, the mechanical wear brings to a specific complication of reverse prostheses, namely scapular notching that according to many publications occurs with a frequency between 62% and 100%.[11,24,25,43]

The prosthetic joint suffers from an inevitable mechanical wear that in time may lead to dislocation of the prosthesis. Currently, a prosthetic vitality of 10 to 15 years is realistic.[2,20,41,56,60] In addition to the specific complications there are also the common complications of each operation, namely thrombosis (about 2%), cardiac stress that can bring to organ malfunctioning (about 2%, very dependent of the age and state of health) and problems of healing (about 1%).

All the procedures in this series were elective primary RTSA and therefore possess a lower complication rate (15%) than revision reverse arthroplasty (40%).[61]

5.4.1 Hematoma and infections compared between approaches

In this study there was only 1 case of hematoma formation (with DP approach) with a percentage of 3.7% within the entire cohort; this result is relatively small compared to the

literature. In 2005 Werner et al. found a percentage of hematoma formation of 21% and explained it by the design of the reverse prosthesis; that left a larger space free of soft tissue after implantation. Additionally, they began physiotherapy before the wound was completely healed with the risk of producing a hematoma.[11]

The infection rate in this study was 0%, as no patient developed any in the time of observation. This is a promising result in respect to other studies but can not be further qualified.[11] It must be stated however that the majority of the operated cases were elective primary and not involving major revision surgeries, which are more prone to infection than primary cases.

5.4.2 Nerve lesions compared between approaches

Lesion of the axillary nerve represents a catastrophic outcome for RTSA, as the restoration of ROM depends entirely on the deltoid function. Statistics in this study did not show a significant difference of axillary lesions between approaches (Table 10; $P > 0.01$) as only 1 case in the SL group has been observed (3.7%). However, the DP is theoretically a safer approach for the protection of this nerve because it lies far away from the musculocutaneous dissection and it can be safely identified during the procedure.[5,7,22] Meanwhile the SL is theoretically a more jeopardizing procedure because of the delta-split. Even if there is a safe zone for this cut (no more than 4 cm distal from the lateral acromion), there is the possibility that retractors or excessive humeral traction could damage the axillary nerve.[4,7,9]

A lesion of the radial nerve during RTSA is often observed as a result of an intraoperative shaft fracture. This occurred once in this series (3.7%, SL group), so that no comparison between the approaches is possible.

5.4.3 Prosthetic loosening compared between approaches

In this study 3 cases (11.1%) of glenoid loosening have been observed, all occurred in the DP group. However, there is no statistical relationship between approaches (Table 10; $P > 0.01$).

Melis et al. reported loosening rates of cemented or uncemented humeral stem to 20% and respectively 8% during a minimum 8-year FU.[55] Glenoid loosening has been reported with an incidence of 2.6% for medialized designs and of 4.6% for lateralized designs, as the second one sustains a bigger mechanical stress that can influence bony ingrowth at the implant interface and thus its long-term stability.[61–63]

Frankle et al. described a critical period of 2 years where loosening of the prosthesis components is most frequent; this is the period of bone ingrowth around the prosthesis

components. When this is not appropriate, mechanical fatigue can happen leading to loosening of the deltoid or humeral prosthesis.[16] This critical period can be altered on behalf of health and bone status of the patients. This means the patient's characteristics, such as the age, are important factors that could play a bigger role than the chosen approach.
Nonetheless the total amount of complications as well as the statistically insignificant higher revision rate with the DP approach is worrying.

5.4.4 Instability compared between approaches

In this study 3 (7.4%) secondary dislocations (due to prosthetic loosening) in the DP group were observed. These results are in line with a multicentric study of 527 RTSA by Molé et al. where they found greater dislocation rates in the DP group.[58] However, they may depend on the type of implant utilized or if they occurred primary or secondary and therefore this cannot be assessed in this study.
If reattachment or preservation of cuff muscles is not essential to restore ROM, maintenance of their insertion may play an important role in the stability of the prosthetic joint, especially in the case of the subscapularis muscle.[4,8,9] For this reason Molé et al. explained in their study that the DP approach favors instability of the prosthetic joint (5.1% with DP and 0.8% with SL) because the subscapularis has to be tenotomized or osteotomized in order to visualize the humeral head.[4,58] Wall et al. explained it by the fact that the DP approach needs an anteroinferior joint capsule release, reducing the buttress on the inferior and anterior joint (where most dislocations occurs).[18] Additionally, even positioning the humeral component with too much retroversion and the glenoid component with too much anteversion could favor instability but this depends rather on the surgeon's experience than of the chosen approach.[4]

5.4.5 Fractures compared between approaches

In this study 2 (7.4%) fractures have been observed. The DP group exhibits an intraoperative shoulder blade strain fracture as "secondary" complication of a glenoid revision. However, it has not been added as a complication as it was already the consequence of one. In the SL group a humeral stem fracture has been observed; it occurred intraoperatively with consequent radialis palsy. Additionally, the patient underwent revision surgery for concomitant loosening of glenoid component; the prosthetic joint was converted into a hemiprosthesis. Because of the variance of both episodes, no comparison between approaches has been performed. Many publications report that the most common fracture post RTSA is

an acromial fracture.[11,41,58,61] This complication seems to be the result of 2 mechanisms; 1) too much intraoperative lengthening of deltoid muscle in case of components misplacing and 2) joint instability that lead to acromial stress fractures. Molé et al. reported in a study that acromial fractures are more frequent with DP approach than with the SL approach.[58] Lädermann et al. performed a study where they described that the humeral cut with SL approach is on average lower than with the DP, so the humerus is less lengthened and the deltoid under less strain. This lower cut can be compensated by a thicker polyethylene cup of the prosthesis, with the advantage of being intraoperatively adapted to the soft tissue tension and to the patient's characteristics.[6]

This finding could theoretically favors the use of an SL approach in RTSA if preoperative acromial malformations or alterations are present. However, this benefit is only theoretical because statistical comparison between the approaches for this complication has not yet been done.

5.4.6 Notching grade compared between approaches

Notching is the most common complication seen with RTSA, and its comparison between approaches has been made in previous chapters (Chapter 5.3.2, Table 11).[30,43]

In most publications, a bigger incidence of notching is correlated with SL approach and even if the clinical consequences of this finding are not unanimously agreed upon, there are simple strategies to minimize the incidence that can be intraoperatively controlled.[30,42,43,61]

As the incidence of it relies mostly on the angular relationship between glenoid component and the glenoid neck, some authors have proposed conditions that do not require a specific modification of the prosthesis design such as choosing a DP approach, implanting the prosthetic baseplate with inferior tilt and with a small distal overhang.[17,26,30,42,43] Lévigne et al. proposed an intraoperative algorithm to adapt the glenoid bone: if it inclines inferiorly, (bigger β angle) the baseplate is implanted without changing its conformation (uniformly reamed). If the glenoid inclines superiorly (smaller β angle), an inferiorly accentuated reaming could be performed in order to restore an optimal glenoid inclination.[43] Moreover, Frankle et al. proposed the use of a more lateralized humeral cup by means of a thicker insert or use of a glenosphere with bigger offset; these small modifications lateralize the center of rotation and thus causes less mechanical impingement in adduction.[17]

5.5 Limitations of the study

There are several limitations to this study design: 1) The number of patients which could be recruited corresponding to the inclusion and exclusion criteria is small and does not allow any subgroup analysis. 2) The complication rate as well as the rate of patients lost to FU is, compared to the literature, unexpectedly high. This can be explained first by the slightly higher mean age (75 years old) of the patients in this study that in multiple occasions, along with comorbidities, interfered with the attendance to regular FU controls. Additionally, a small cohort magnifies the percentage of the FU-losses and complications in rapport to other study with hundreds of patients. 3) This study compared the approaches in a short-term observation; more extended FU period has to be necessary in order to perform an exhaustive outcomes comparison between surgical techniques. 4) One single type of implant with a particular instrument set was used. It may be that specific instrumentation available for either approach or implant design could improve the results of one or the other approach so that the data do not have sufficient external reproducible validity.

5.6 Advantages and disadvantages of the approaches

5.6.1 Deltopectoral approach

Advantages. The DP approach follows an internervous plane, limiting the risk of damaging nerves and blood vessels.[5,22] In this approach the deltoid muscle is not dissected; theoretically the future shoulder motor is not damaged or altered. There are no cases of deltoid dehiscence or rupture in the English literature.[15,17,18,50,58,64] Additionally, the DP approach allows good visualization and protection of the axillary nerve, provided the surgeon is experienced with this approach.[5] The glenoid surface in the DP approach can be put in relationship with the frontal plane and the inferior glenoid surface is clearly visible. This eases the resection of osteophytes and baseplate implantation. These are the reasons because some authors maintain that the DP is associated with less notching and dislocation.[17,43,55,58] Additionally, the DP approach can be extended in order to treat any intraoperative complications including humeral stem fracture.[5,7,22] Intraoperatively, the DP allows a good circumferential capsular release, improving the visualization of important structures and improving postoperative ROM in particularly tight shoulders.[4,8] For practical reasons, the DP approach is ideal for revision surgery.[6,13] If ER is a priority for the patient,

the DP approach allows a combined RTSA with latissimus dorsi transfer as does the SL approach.[3,50,53]

Disadvantages. The cephalic vein lies in the deltopectoral groove and can be damaged through the surgery by retractors.[4,5,7,51] DP approach in obese patients provides only a restricted access to the area.[7] The posterior glenoid is difficult to be visualized and there is the risk to place the baseplate with an anterior tilt, increasing the risk of joint instability.[8,18,58] Additionally, with this approach the subscapularis has to be released. This is often the only intact muscle in CTA and it is important for joint stability and potentially for restoration of active IR.[5,7,9] The DP approach is associated with the risk of too much lengthening of the humerus and the deltoid and may favor acromial stress fractures.[6] The DP approach has some disadvantages when a patient undergoes previous mini-open or open shoulder operation (risk of deltoid lesions), as with this approach the deltoid origin cannot be inspected and eventually repaired.[64]

5.6.2 Superolateral approach

Advantages. The SL approach allows reattaching of the deltoid, even if dissected, it can very well be reattached without compromising the functional clinical outcome after RTSA.[9] The antero-inferior aspect of the joint capsule and part of the subscapularis can be kept in place, which may decrease the instability rate and may help to preserve or even restore active IR.[18] The posterior aspect of the glenoid is well visualized and with this also the posterior cuff muscles.[4,9] With this approach there is the possibility to maintain the coracoacromial ligament. For example, if the cuff tear is reparable and when this ligament is maintained, implant stability may be improved.[9] The visualization of the deltoid origin allows a repair of it when prior damaged by mini-open or open surgery.[64] The SL approach does not forcedly require cuff muscle dissection, thus these soft tissues allow less lengthening of the humerus and thus less risk of stress fractures.[6,58]

Disadvantages. The SL approach splits the deltoid and it seems controversial to dissect the future motor of the reverse prosthesis; as there is the risk of deltoid dehiscence, even if it is very minimal.[4,9] Additionally, the deltoid muscle has no tendinous insertion to the humeral head, so “en-bloc” dissection with a sheet of periosteum has to be carried out with care and it is a rather difficult operation.[9] Theoretically, during the dissection or by too much tension on the retractors, there is the risk of axillary lesions.[5,7,9,13] The SL approach is associated

with more glenoid dislocation and notching because of the difficulty to place the baseplate in a proper, inferior way.[17,20,26] Additionally, SL approach could not be extended as the DP, so it is a drawback when CTA is associated with a humeral fracture below the metaphysis.[5–7,13] Similarly, the access to the deltoid is space-limited by the axillary nerve that passes 4 cm below the lateral surface of the acromion.[7,9]

6 Conclusion

Both surgical approaches yield similar short-term outcome and not statistically significant differences in the complication rates after RTSA. All outcomes parameters analyzed in this study did not show significant differences between these two approaches.

The main drawback of this study is the small sample size. However, it has to be considered to be a pilot study. It may help to justify continuing the preferred approach until large-scale studies are available which prospectively compare the results in very large samples. Multicenter trials and/or registry data studies may be needed to definitively answer the question of superiority of one approach over the other.

Various other publications pointed out specifics particularities of each approach that could orientate the surgeon to preferably choosing one over the other. This depends strongly on patient's characteristics and preoperative patient's assessment as well as the surgeon's preference and experience for one approach.

Even if this study failed to statistically define a "gold standard" approach, a review of the literature can summarize some particular peculiarities of each approach in order to offer some preoperative recommendations.

If there is a high risk to postoperative glenoid dislocation, for example poor scapular bone stock, it may be best to use a DP approach, in order to optimally implant the baseplate. If notching or dislocations are the main concern, inferior tilt of the baseplate is considered to be important and can be achieved more easily with a DP approach.

When the affected shoulder already underwent open or mini-open cuff repair, it is possible that the deltoid origin can be damaged. In this case it is best to utilize a SL approach, because of the possibility to fully assess the deltoid origin and eventually to repair it. In case of intact subscapularis muscle or if prosthesis stability is an absolute priority, it is probably preferable to utilize the SL approach; this preserves the subscapularis tendon attachment and limits the risk of prosthesic dislocation.

7 Appendix

7.1 Bibliography

1 Holschen M, Agneskirchner J. Inverse Schulterprothese – Indikation, Operationstechnik und Ergebnisse. *Arthroskopie* 2014;**27**:38–48.

2 Gerber C, Wirth SH, Farshad M. Treatment options for massive rotator cuff tears. *J Bone Jt Surg* 2011;**20**:S20–9.

3 Khair MM, Gulotta L V. Treatment of irreparable rotator cuff tears. *Curr Rev Musculoskelet Med* 2011;**4**:208–13.

4 Molé D, Wein F, Dézaly C, *et al*. Surgical technique: The anterosuperior approach for reverse shoulder arthroplasty. *Clin Orthop Relat Res* 2011;**469**:2461–8.

5 Gadea F, Bouju Y, Berhouet J, *et al*. Deltopectoral approach for shoulder arthroplasty: anatomic basis. *Int Orthop* 2015;**39**:215–25.

6 Lädermann A, Lubbeke A, Collin P, *et al*. Influence of surgical approach on functional outcome in reverse shoulder arthroplasty. *Orthop Traumatol Surg Res* 2011;**97**:579–82.

7 Joyce JJ, Harty M. Surgical Exposure of the Shoulder. *J Bone Jt Surg Am* 1967;**49**:547–54.

8 Gillespie RJ, Garrigues GE, Chang ES, *et al*. Surgical Exposure for Reverse Total Shoulder Arthroplasty. Differences in Approaches and Outcomes. *Orthop Clin North Am* 2015;**46**:49–56.

9 Dumontier C, Sautet A, Apoil A. The Superolateral Approach to the Shoulder. *Maîtrise Orthopédique* 1997;**68**.

10 Neer CI, Craig EV, Fukuda H. Cuff-Tear Arthropathy. *J Bone Jt Surg Am* 1983;**65**:1232–44.

11 Werner CML, Steinmann P, Gilbart M, *et al*. Treatment of Painful Pseudoparesis Due to Irreparable Rotator Cuff Dysfunction with the. *J Bone Jt Surg Am* 2005;**87**:1476–86.

12 Kappe T, Cakir B, Reichel H, *et al*. Reliability of radiologic classification for cuff tear arthropathy. *J Bone Jt Surg* 2011;**20**:543–7.

13 Gerber C, Pennington S, Nyffeler RW. Reverse total shoulder arthroplasty. *J Am Acad Orthop Surg* 2009;**17**:284–95.

14 Nam D, Maak T, Raphael B, *et al*. Rotator cuff tear Arthropathy: Evaluation,

Diagnosis, and Treatment. *J Bone Jt Surg Am* 2012;**94**:1–11.

15 Guery J. Reverse Total Shoulder Arthroplasty: Survivorship Analysis of Eighty Replacements Followed for Five to Ten Years. *J Bone Jt Surg Am* 2006;**88**:1742.

16 Frankle M, Siegal S, Pupello D, *et al*. The Reverse Shoulder Prosthesis for Glenohumeral Arthritis Associated with Severe Rotator Cuff Deficiency. A Minimum Two-Year Follow-Up Study of Sixty Patients. *J Bone Jt Surg Am* 2005;**87**:1697–705.

17 Frankle M, Siegal S, Pupello D, *et al*. The Reverse Shoulder Prosthesis for Glenohumeral Arthritis Associated with Severe Rotator Cuff Deficiency. A Minimum Two-Year Follow-Up Study of Sixty Patients. Surgical Technique. *J Bone Jt Surg Am* 2006;**88**:178–90.

18 Wall B, Nové-Josserand L, O'Connor D, *et al*. Reverse Total Shoulder Arthroplasty: A Review of Results According to Etiology. *J Bone Jt Surg Am* 2007;**89**:1476–85.

19 Flatow EL, Harrison AK. A history of Reverse Total Shoulder Arthroplasty. *Clin Orthop Relat Res* 2011;**469**:2432–9.

20 Matsen FA, Clinton J, Lynch J, *et al*. Glenoid Component Failure in Total Shoulder Arthroplasty. *J Bone Jt Surg Am* 2008;**90**:885–96.

21 Grammont P, Trouilloud P, Laffay J, *et al*. [Etude et réalisation d'une nouvelle prothèse s'épaule]. *Rhumatologie* 1987;**10**:407–18.

22 McCluskey GMI, Routman HD. The Deltopectoral Approach for Reverse Shoulder Arthroplasty. *St Fr Orthop Inst Sci Bull* 2011;**3**:148–60.

23 Walker M, Brooks J, Willis M, *et al*. How reverse shoulder arthroplasty works. *Clin Orthop Relat Res* 2011;**469**:2440–51.

24 Boileau P, Watkinson DJ, Hatzidakis AM, *et al*. Grammont reverse prosthesis: Design, rationale, and biomechanics. *J Bone Jt Surg* 2005;**14**:147–61.

25 Sirveaux F, Favard L, Oudet D, *et al*. Grammont inverted total shoulder arthroplasty in the treatment of glenohumeral osteoarthritis with massive rupture of the cuff. Results of a multicentre study of 80 shoulders. *J Bone Jt Surg Br* 2004;**86**:388–95.

26 Nyffeler RW, Werner CML, Gerber C. Biomechanical relevance of glenoid component positioning in the reverse Delta III total shoulder prosthesis. *J Bone Jt Surg* 2005;**14**:524–8.

27 Nyffeler RW, Werner CML, Simmen BR, *et al*. Analysis of a retrieved delta III total shoulder prosthesis. *J Bone Jt Surg Br* 2004;**86**:1187–91.

28 Constant C, Murley A. A clinical method of functional assessment of the shoulder. *Clin Orthop Relat Res* 1987;:160–4.

29 Constant C, Gerber C, Emery RJ, *et al*. A review of the Constant score: Modifications and guidelines for its use. *J Bone Jt Surg* 2008;**17**:355–61.

30 Simovitch RW. Predictors of Scapular Notching in Patients Managed with the Delta III Reverse Total Shoulder Replacement. *J Bone Jt Surg Am* 2007;**89**:588.

31 Seidl AJ, Williams GR, Boileau P. Challenges in Reverse Shoulder Arthroplasty: Addressing Glenoid Bone Loss. *Orthopedics* 2016;**39**:14–23.

32 Bercik MJ, Kruse K, Yalizis M, *et al*. A modification to the Walch classification of the glenoid in primary glenohumeral osteoarthritis using three-dimensional imaging. *J Bone Jt Surg* 2016;**25**:1601–6.

33 Walch G, Badet R, Boulahia A, *et al*. Morphologic study of the glenoid in primary glenohumeral osteoarthritis. *J Arthroplasty* 1999;**14**:756–60.

34 Favard L, Lautmann S, Clement P. Osteoarthritis with Massive Rotator Cuff-Tear: The Limitation of its Current Definitions. In: *Shoulder Arthroplasty*. 1999. 261–5.

35 Hamada K, Fukuda H, Mikasa M, *et al*. Roentgenographic findings in massive rotator cuff tears. A long-term observation. *Clin Orthop Relat Res* 1990;92–6.

36 Hamada K, Yamanaka K, Uchiyama Y, *et al*. A radiographic classification of massive rotator cuff tear arthritis. *Clin Orthop Relat Res* 2011;**469**:2452–60.

37 Friedman RJ, Hawthorne KB, Genez BM. The use of computerized tomography in the measurement of glenoid version. *J Bone Jt Surg Am* 1992;**74**:1032–7.

38 Goutallier D, Postel JM, Bernageau J, *et al*. Fatty muscle degeneration in cuff ruptures. Pre- and postoperative evaluation by CT scan. *Clin Orthop Relat Res* 1994;:78–83.

39 Maurer A, Fucentese SF, Pfirrmann CWA, *et al*. Assessment of glenoid inclination on routine clinical radiographs and computed tomography examinations of the shoulder. *J Bone Jt Surg* 2012;**21**:1096–103.

40 Sirveaux F. [Grammont prosthesis in the treatment of shoulder arthropathies with massive cuff tear. Multicenter series of 42 cases (in French)]. *Med Dr thesis, Nancy I Univ* 1997.

41 Farshad M, Gerber C. Reverse total shoulder arthroplasty-from the most to the least common complication. *Int Orthop* 2010;**34**:1075–82.

42 Nicholson GP, Strauss EJ, Sherman SL. Scapular notching: Recognition and strategies to minimize clinical impact. *Clin Orthop Relat Res* 2011;**469**:2521–30.

43 Lévigne C, Boileau P, Favard L, *et al*. Scapular notching in reverse shoulder arthroplasty. *J Bone Jt Surg* 2008;**17**:925–35.

44 Rittmeister M, Kerschbaumer F. Grammont reverse total shoulder arthroplasty in patients with rheumatoid arthritis and nonreconstructible rotator cuff lesions. *J Bone Jt Surg* 2001;**10**:17–22.

45 Favard L, Levigne C, Nerot C, *et al*. Reverse prostheses in arthropathies with cuff tear are survivorship and function maintained over time? *Clin Orthop Relat Res* 2011;**469**:2469–75.

46 Walton MJ, Walton JC, Honorez LAM, *et al*. A comparison of methods for shoulder strength assessment and analysis of Constant score change in patients aged over fifty years in the United Kingdom. *J Shoulder Elb Surg* 2007;**16**:285–9.

47 Bankes MJ, Crossman JE, Emery RJ. A standard method of shoulder strength measurement for the Constant score with a spring balance. *J Shoulder Elb Surg* 1998;**7**:116–21.

48 Boileau P, Gonzalez JF, Chuinard C, *et al*. Reverse total shoulder arthroplasty after failed rotator cuff surgery. *J Shoulder Elb Surg* 2009;**18**:600–6.

49 Torrens C, Guirro P, Santana F. The minimal clinically important difference for function and strength in patients undergoing reverse shoulder arthroplasty. *J Shoulder Elb Surg* 2016;**25**:262–8.

50 Boileau P, Chuinard C, Roussanne Y, *et al*. Reverse shoulder arthroplasty combined with a modified latissimus dorsi and teres major tendon transfer for shoulder pseudoparalysis associated with dropping arm. *Clin Orthop Relat Res* 2008;**466**:584–93.

51 Mackenzie D. The antero-superior exposure for total shoulder replacement (T.S.R.). *Orthop Traumatol* 1993;**2**:71–7.

52 RockwoodJr CA. The Reverse Total Shoulder Prosthesis: The New Kid on the Block. *J Bone Jt Surg Am* 2007;**89**:233.

53 Ortmaier R, Resch H, Hitzl W, *et al*. Reverse shoulder arthroplasty combined with latissimus dorsi transfer using the bone-chip technique. *Int Orthop* 2014;**38**:553–9.

54 Gutiérrez S, Walker M, Willis M, *et al*. Effects of tilt and glenosphere eccentricity on

baseplate/bone interface forces in a computational model, validated by a mechanical model, of reverse shoulder arthroplasty. *J Bone Jt Surg Am* 2011;**20**:732–9.

55 Melis B, Defranco M, Lädermann A, *et al*. An evaluation of the radiological changes around the Grammont reverse geometry shoulder arthroplasty after eight to 12 years. *J Bone Jt Surg Br* 2011;**93**:1240–6.

56 Delloye C, Joris D, Colette A, *et al*. [Mechanical complications of total shoulder inverted prosthesis]. *Rev Chir Orthop Reparatrice Appar Mot* 2002;**88**:410–4.

57 Zumstein MA, Pinedo M, Old J, *et al*. Problems , complications , reoperations , and revisions in reverse total shoulder arthroplasty : A systematic review. *J Shoulder Elb Surg* 2011;**20**:146–57.

58 Molé D, Favard L. Excentered scapulohumeral osteoarthritis. *Rev Chir Orthop Reparatrice Appar Mot* 2007;**93**:37–94.

59 Trappey GJ, O'Connor DP, Bradley Edwards T. What are the instability and infection rates after reverse shoulder arthroplasty? *Clin Orthop Relat Res* 2011;**469**:2505–11.

60 Walch G, Bacle G, Lädermann A, *et al*. Do the indications, results, and complications of reverse shoulder arthroplasty change with surgeon's experience? *J Bone Jt Surg* 2012;**21**:1470–7.

61 Barco R, Savvidou OD, Sperling JW, *et al*. Complications in reverse shoulder arthroplasty. *Shoulder Elb* 2016;**1**:72–80.

62 Alentorn-Geli E, Guirro P, Santana F, *et al*. Treatment of fracture sequelae of the proximal humerus: comparison of hemiarthroplasty and reverse total shoulder arthroplasty. *Arch Orthop Trauma Surg* 2014;**134**:1545–50.

63 Harman M, Frankle M, Vasey M, *et al*. Initial glenoid component fixation in 'reverse' total shoulder arthroplasty: a biomechanical evaluation. *J Shoulder Elb Surgeryhoulder Elb Surg* 2003;**14**:162S–167S.

64 Whatley AN, Fowler RL, Warner JJP, *et al*. Postoperative rupture of the anterolateral deltoid muscle following reverse total shoulder arthroplasty in patients who have undergone open rotator cuff repair. *J Bone Jt Surg* 2011;**20**:114–22.

7.2 List of abbreviations

AHI = acromiohumeral interval

CR = conventional radiography

CS = Constant score

CT = computed tomography

CTA = cuff tear arthropathy

DP = deltopectoral

ER = external rotation

FU = follow-up

IQR = interquartiles range

IR = internal rotation

ROM = range of motion

RTSA = reverse total shoulder arthroplasty

SL = superolateral

SSV = subjective shoulder value

SSF = specific shoulder's functions

VAS = visual analog scale

7.3 Acknowledgement

I would like to thank all the people who contributed to the work of this master thesis. First and foremost, I thank my thesis advisor Professor Dr. med. Christian Gerber, medical director of Balgrist University Hospital and full Professor and Chairman of the Department of Orthopaedics of Zurich University for allowing me to perform my first research work and for the precious guidance through the writing of the thesis.

I would also like to acknowledge Sabrina Catanzaro of the Balgrist University Hospital for welcoming me into the Campus, for the help in data analysis and for the helpfulness for advices and consults through the writing.

Regarding the data collection, I would like to thank all the researchers that performed it and permitted me to elaborate it into a master thesis.

I would also like to thank Professor Dr. Burkhardt Seifert, adjunct Professor of the Epidemiology, Biostatistics and Prevention Institute of Zurich University for the valuable help in the statistics section.

Finally, I would also like to acknowledge Dr. med. Stéphanie Hinse, Fellow of the Royal College of Surgeons of Canada for a first reading of this thesis. I am gratefully indebted to her helpfulness and valuable comments.

7.4 Curriculum Vitae

Name:	Ottini, Andrea Ivo
Sex:	Male
Date of birth:	07.07.1991
Place of birth:	Bellinzona, TI

Education:

Primary school (1996-2001, Scuole elementari Arbedo-Castione, Arbedo-Castione)

Secondary school (2001-2006, Scuole medie Arbedo-Castione, Arbedo-Castione)

High school (2006-2010, Liceo cantonale Bellinzona, Bellinzona) with focus: Biology and chemistry

Biomedical Science (2011-2012, University Fribourg, Fribourg FR)

Bachelor study human medicine (2012-2015, University Fribourg, Fribourg FR)

Master study human medicine (2015-ongoing, University of Zürich, Zürich ZH)

8 Statement of authorship

Ich erkläre ausdrücklich, dass es sich bei der von mir im Rahmen des Studiengangs

Humanmedizin

eingereichten schriftlichen Arbeit mit dem Titel

“Deltopectoral versus Superolateral Approach for Reverse Shoulder Arthroplasty”

um eine von mir selbst und ohne unerlaubte Beihilfe sowie *in eigenen Worten* verfasste Masterarbeit* handelt.

Ich bestätige überdies, dass die Arbeit als Ganzes oder in Teilen weder bereits einmal zur Abgeltung anderer Studienleistungen an der Universität Zürich oder an einer anderen Universität oder Ausbildungseinrichtung eingereicht worden ist.

Verwendung von Quellen

Ich erkläre ausdrücklich, dass ich *sämtliche* in der oben genannten Arbeit enthaltenen Bezüge auf fremde Quellen (einschliesslich Tabellen, Grafiken u. Ä.) als solche kenntlich gemacht habe. Insbesondere bestätige ich, dass ich *ausnahmslos* und nach bestem Wissen sowohl bei wörtlich übernommenen Aussagen (Zitaten) als auch bei in eigenen Worten wiedergegebenen Aussagen anderer Autorinnen oder Autoren (Paraphrasen) die Urheberschaft angegeben habe.

Sanktionen

Ich nehme zur Kenntnis, dass Arbeiten, welche die Grundsätze der Selbstständigkeitserklärung verletzen – insbesondere solche, die Zitate oder Paraphrasen ohne Herkunftsangaben enthalten –, als Plagiat betrachtet werden und die entsprechenden rechtlichen und disziplinarischen Konsequenzen nach sich ziehen können (gemäss §§ 7ff der Disziplinarordnung der Universität Zürich sowie §§ 51ff der Rahmenverordnung für das Studium in den Bachelor- und Master-Studiengängen an der Medizinischen Fakultät der Universität Zürich).

Ich bestätige mit meiner Unterschrift die Richtigkeit dieser Angaben.

Datum: 20.10.2017

Name: Ottini Vorname: Andrea

Unterschrift:…… *nur auf Printversion erforderlich*

* Falls die Masterarbeit eine Publikation enthält, bei der ich Erst- oder Koautor/-in bin, wird meine eigene Arbeitsleistung im Begleittext detailliert und strukturiert beschrieben.